INTEGRATION OF GRADUATE EMPLOYABILITY SKILLS THROUGH INDUSTRY OUTSOURCED CDIO PROJECT

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ABSTRACT

Engineering curricula in higher education should be aligned with the current and future requirements of the industry to ensure industry-ready graduates. In the UK GOV HE education and professional accredited bodies, it is required to embed graduate attributes into the engineering curriculum. Although the CDIO-based approach provides a platform where students can develop these skills, there is still a gap between students' skills and industry compatibility due to a lack of interaction with industry. Our solution is to embed industry outsourced CDIO projects in modules across the engineering course curriculum. These modules provide students not only the opportunity to develop their engineering technical skills but also their employability skills for actual industrial environment.

At our university, the academic team have adopted a robust 7-stage approach in consultation and collaboration with industry to identify and implement industry-sourced CDIO projects in the curriculum. Based on the nature and complexity of the project, the CDIO projects can be integrated into relevant modules at appropriate academic levels. For example, a design-related project can be integrated into the first-year module whereas complex projects are allocated to final-year students. The final objectives of the CDIO projects are aligned with the learning outcomes of the corresponding modules and should be reflected in the module assessments. In this paper, the approach and outcome of one of our industrial CDIO projects outsourced by eXroid (a biomedical company in the UK) have been described. During the period, students followed the four stages of CDIO framework. The performance of the students was satisfactory as 81% of the students passed the module on their first attempt and the average mark was 49.9. The feedback received from eXroid personnel and students regarding the project execution and outcome was outstanding. Students have also developed several industry-oriented technical and soft skills while executing the projects.

KEYWORDS

Graduate employability skills, CDIO project, Industry-oriented skills, Engineering curricula, Module mapping

INTRODUCTION

Students should be adaptive in this competitive world to become industry-ready graduates who can easily blend with the current job roles of the industry as proposed by professional accredited bodies (for example in the UK IET, IMechE) for higher education institutions. The top ten graduate employability skills (Atkinson & Bonfield, 2022; Engineering Council, 2020) sorted by large, medium and small enterprises are commercial awareness, communication, teamwork, negotiation and persuasion, problem-solving, leadership, organization, perseverance and motivation, ability to work under pressure and confidence (Archer & Davison, 2008; Jobs, 2019). To incorporate graduate employability skills in the engineering curriculum, integration of both technical skills and soft employability skills are necessary. After investigating the several pedagogic learning methods, the CDIO approach (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014) appears to be an effective way for implementing employability skills in STEM areas as it incorporates several pedagogical approaches together (Manna, S., Nortcliffe, & Sheikholeslami, 2020) such as problem-based learning (Savery, 2015), project-based learning (Pee & Leong, 2005), experimental learning (Tien, Namasivayam, & Ponniah, 2021) etc. However, there is still a gap between the engineering skill set and the expectations of the industry (Radermacher, Walia, & Knudson, 2014). If students do not have the opportunity to interact with industry, they would not understand the business perspectives, commercial viability and critical industrial standards of their developed project, and how to present the project in front industry panel. The integration of employability skills can be achieved through several methods (Arlett, Lamb, Dales, Willis, & Hurdle, 2010) including the use of industry-related problems in teaching and learning, relevant case studies, modifying curricula with the current industry trends, allocation of professional skills-building courses in the curriculum, workshops delivered by industry experts and career enterprise team and collaboration with industry.

Alongside traditional approaches such as problem-based learning (Savery, 2015) and project-based learning (Pee & Leong, 2005), several customized approaches have been incorporated such as Project Centered Curriculum (PCC) developed by the University of Queensland (Crosthwaite, Cameron, Lant, & Litster, 2006), industry-collaborated capstone projects as a community of practice (CoP) model developed by University of Liverpool (Topping & Murphy, 2022), open-ended major group based design projects by the University of Botswana (Moalosi, Oladiran, & Uziak, 2012) and Work-based learning model with partnerships considered by Politeknik Ungku Omar, Malaysia (Tuselim, Muhammad, & Mai, 2020). However, there is always a lack of direct involvement of industry, the opportunity to work under real-time industrial problems and customization of CDIO projects for specific levels of students.

To integrate engineering skill sets as per the industry expectations, we adapted industry outsourced CDIO projects through collaboration with industry partners. The CDIO framework emphasizes the integration of engineering theory and practice, and industry-outsourced projects provide students with the opportunity to apply their technical and employability skills and knowledge in real-world settings such as problem-solving, critical thinking, communication, teamwork etc (Archer & Davison, 2008). These skills are highly sought after by employers and are essential for graduates to be successful in their careers. Besides, industry partners can provide valuable input on the types of skills that graduates need to be successful in their careers and can assist in the design of projects that incorporate these skills. Collaboration with industry partners can also provide students with valuable networking opportunities and can increase the chances of students being employed by the collaborating company after graduation (Freitas, Marques, & e Silva, Evando Mirra de Paula, 2013). Existing research on the integration of graduate employability skills through industry-collaborated student projects has to be effective in preparing engineering graduates for successful careers (Podolskiy et al., 2018). A case study has highlighted the importance of careful curricular design in integrating employability skills through client-sponsored student projects (Bove & Davies, 2009). To integrate the benefits of the CDIO method and industry expertise, we collaborate with local small and medium-sized enterprises in the design and implementation of student-led CDIO projects. To execute the process efficiently, a novel and carefully designed approach is considered so that graduates who will participate in industry-outsourced CDIO projects tend to have better employment outcomes. A case study is discussed based on the above approach which is also proved to be effective and impactful in our curricula.

METHODOLOGY

In consultation and collaboration with the industry, a robust 7-stage approach (CAMIIRI model) is adopted to implement industry-sourced CDIO projects in the curriculum (Figure 1). The process consists of the collection of the CDIO projects, analysis of the depth and level of the projects, mapping the project objectives with the module learning outcomes, integration of the CDIO projects with specific modules, implementation of the four steps of the CDIO framework, reflection on the impact of the project outcomes, further improvement of the overall process.

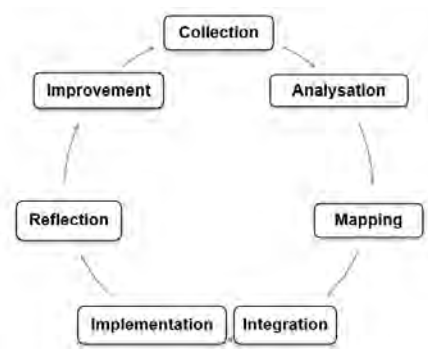

Figure 1. 7 Stage approach (CAMIIRI model)

First of all, we identify the feasible problems from the local industries through industrial visits, consulting with industry contacts, the university's industry liaison officer or the career and enterprise team.

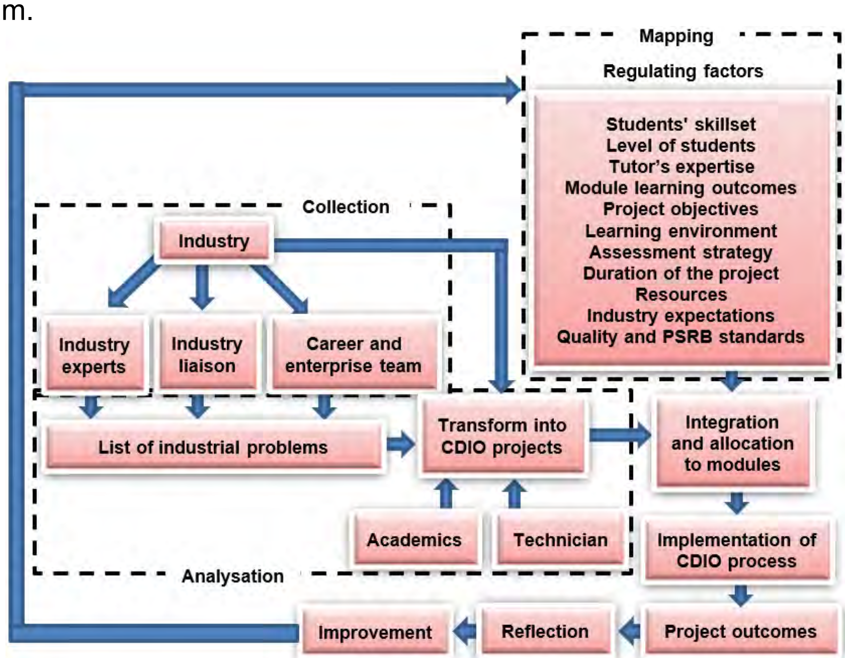

Figure 2. Implementation strategy of CDIO project

Only those industrial problems are usually considered if can be solved at the student level, no such research-intensive projects are not considered for CDIO projects. After that, those current industrial problems are transformed into potential CDIO projects in collaboration with relevant industry partners. The project transformation process is designed by keeping the students' mindset and their skillset in mind so that those projects can be achieved in the academic environment and the project's outcome should meet the required objectives of industry experts (Figure 2). Based on the nature and complexity of the projects, those projects are integrated into relevant modules and allocated to appropriate academic levels.

For example, an investigation-based research study or conceptual-model-based project is allocated for foundation year engineering students; a basic design-related project with a working prototype can be integrated into the first-year design module; a working prototype with a basic experimental study can be integrated with second-year module whereas high-tech and complex projects where commercial perspective is explored, hence would be allocated to final-year students. The process of integration is carried out very cautiously because there are several major factors involved in it such as students' skillset and levels, tutor's and technicians' expertise, module learning outcomes, project objectives, learning environment, assessment strategy, industry expectations, Quality and PSRB standards, duration of the project and resources (Figure 3). It is important to map those regulating factors with module descriptors and CDIO project objectives so that specific CDIO projects can be allocated to appropriate modules. Students' skill sets of specific levels should align with the project's complexity so that it will be achievable within the timeline with adequate resources, usually within a semester. Sometimes one CDIO project is spread across two semesters based on the module descriptor. Also, the project should be completed by a group of students rather than individuals where each team member will contribute, exchange their ideas and support to achieve the final goal. The expertise of associated module tutors and technicians plays a major role in executing the project, for example, if the tutors cannot provide enough technical and professional support, it would not be beneficial for students to complete the project efficiently.

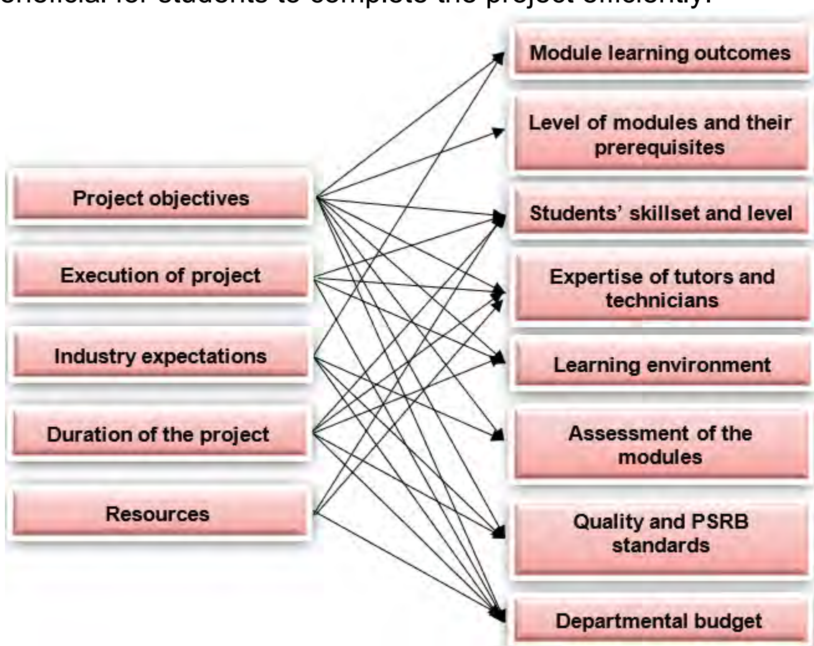

Figure 3. Mapping CDIO projects into a module

Alongside this, it would also need support from other co-tutors in case of more students. To maintain the quality of learning and teaching, we need to keep the staff and student ratio 20:1

at CCCU, hence there will be more tutors and technicians in the classroom for supporting a large number of students. The module learning outcomes and project objectives should be coherent. For integration purposes, the modules' learning outcomes are analysed in advance and only those CDIO projects are considered a part of the course if their objectives help to satisfy the module learning outcomes. There are some expected outcomes from the projects as suggested by industry experts, hence those expectations are usually conveyed to the students as their project objectives. The learning outcomes of the specific modules and the objectives of the CDIO projects are clearly defined to students with a clear focus with the aim to prevent project creep, however the key to prevent the latter is good academic support and team management (Anslow & Maurer, 2015). Therefore, the students were guided, managed and assessed by academic and industry experts. It is the responsibility of the module leader to design the learning environment for executing the CDIO project effectively. The learning sessions are divided into two sections: lectures (technical and professional) and practical sessions. Technical knowledge and professional skills are delivered by module tutors through lecture sessions which are beneficial for designing their projects and executing the project whereas practical sessions are dedicated to develop the final product. Our technicians usually help the students with technical support and resources. The learning sessions are arranged logically to facilitate the four stages of CDIO (Figure 4), for example, in the first two weeks, active learning session rooms are scheduled in the timetable so that students can complete the conceive part of the CDIO process through literature survey and brainstorming sessions in a group; for the next three weeks, the IT rooms are booked where students can design the 3D model and electronics design in simulation platform using several software; in the next three weeks, electromechanical lab, 3D printer and mechanical workshops are open for students to implement the project by developing the prototypes and electronics hardware circuit; in the last two weeks, the makerspace and mechanical testing labs are used by the students so that they can operate through experimental study for further improvements. All these sessions are supported by module tutors and technicians for technical or professional guidance.

CDIO stages	**Conceive**		**Design**			**Implement**			**Operate**			**Assessment support**
Week	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Sessions	Active learning lab		IT room (with relevant software)			3D printing lab, Electronics lab, Mechanical workshop			Makerspace, Material testing lab			Working on project reports and presentations
Student Activities	Understand the aims and objectives of the project Group work, Literature survey, brainstorming sessions to develop the concept.		Design 3D model, electronics circuit simulation/ mathematical models.			Develop mechanical prototype, electronic hardware. Implement programming if required.			Experiment to understand its working principle for further improvement			Review of individual technical/ business report Group Poster/ PPT presentation
Skills learned	Critical thinking Project investigation Communication Teamwork Project management Organisation Motivation		Technical skills (3D modelling, circuit design) Commercial awareness Negotiation Persuasion Problem- solving Leadership Teamwork Confidence Organisation			Technical skills (3D printing, circuit making) Problem-solving Ability to work under pressure Leadership Teamwork Organisation Hands-on skill			Critical thinking Teamwork Hands-on skill Organisation			Presentation Report writing Confidence Perseverance

Figure 4. Planned learning for CDIO projects

INTEGRATION OF GRADUATE EMPLOYABILITY SKILLS

Students will learn several technical and professional skills while pursuing the CDIO stages, for example, they can enhance their critical learning skills during the Conceive stage, problem-solving skills during the Design stage, and hands-on skills during the Implement and Operate stage. To adapt to the current HEI engineering framework, the course learning outcomes are validated based on Engineering Council AHEP 4.0 standards (Engineering Council, 2020). The technical and professional skills learnt during the CDIO projects can be mapped as fulling the graduate employability skillset as per the PSRB standards, and the project execution and outcomes are aligned with the university's quality framework. It is necessary to maintain the module credit, assessment policy, module learning outcomes, course contents, and contract hours for each module, hence the project objectives are nicely fitted into the module without overburdening the students. The required resources for the CDIO project are usually allocated from the departmental budget, something a few specific items are outsourced from the industry for experimental purposes. Maintaining affordability is always a challenge for CDIO projects, hence we always try to keep the overall budget within a limit so that it is feasible to finance. The students usually submit the list of resources, with their specifications, cost and links to the module leader. The list is reviewed by the module tutors and technicians. It is our recommendation to allocate in-house resources for the CDIO projects, otherwise purchased if required. Most of the time, students end up building a working prototype to provide the conceptual model rather than the actual commercial product due to the restriction of budget and prevent project creep as keeps tight focus, however, it still allows students to develop all these graduate skills set while developing the product.

Critical thinking is embedded into the process by promoting student-led and tutor-guided CDIO projects. Starting from the conceptual model, feasible solutions to the final prototypes are delivered by the students whereas tutors and technicians provide knowledge, technical and professional support whenever required. Hence it is possible to enhance the critical thinking and innovative mindset of students. Group work and team spirit are always nurtured through CDIO projects. To remove this conflict of engagement and to allow every group member to participate actively, the overall task of a project is allocated among the group members with sub-tasks and each member is assigned to fulfil the responsibility of the specific part of the project. All students are recommended to create a shared folder to share their individual progress with other team members. The advantage of such an approach is to ensure the team working is inclusive as it provides each student with the opportunity to develop their technical and employability skills. Despite the individual tasks in a group, students are still encouraged to support one another seeding teamwork skills. Besides, a certain percentage of the final assessment is kept as a peer assessment (Brown, 2015) where students will mark each other based on contribution and engagement in the project, hence each of the team members has the responsibility to drive the rest of the members to contribute to the project otherwise, the overall outcome would be degraded (Nortcliffe, 2012).

A discussion room was created on the blackboard module site to provide asynchronous support, and enabled students to share their weekly progress, doubts and receive academic feedback on areas to improve. Students from different courses such as mechanical, biomedical and product design engineering can participate to make a multidisciplinary project group, work together, share knowledge and innovate solutions. While developing the projects, students will also learn project management skills, leadership, organizational skills, communication with teammates and motivation to carry out the projects. They can learn and enhance several technical skills in software and simulation tools which will provide evidence for their CV for future job opportunities. Problem-solving skill is underpinned in each stage of the framework as the projects requires the students to work together to solve unknown engineering problems outsourced by industry whereas producing the product within the proposed deadline can improve their ability to work under pressure. The assessment strategy of the modules is one of the important factors. As the CDIO project is now an integral part of a module, its outcomes should be reflected in the module assessments as well. Based on the module validation document, group assessment (presentation/poster/report) or individual assessment (technical/business) are kept for formative/ summative assessment of a module. The aim of the module assessments was focused on empowering the presentation skill, report writing and confidence of students. Out of four assessments in the module, two assessments (group poster and individual technical report) are associated with the CDIO project. Another piece of assessment is reflective writing where students show their learning process throughout the project execution.

RESULTS

In this section, a case study on an industry outsourced CDIO project is discussed. In the last academic year, a CDIO project was outsourced by eXroid (a biomedical company in the UK) and executed during the second phase of COVID-19 restrictions, so an optimal arrangement of a blended learning approach (Manna, Soumya, Battikh, Nortcliffe, & Camm, 2022) was adopted. Lectures were delivered online whereas weekly practical sessions were arranged in person. The CDIO project aims are incorporated into the learning outcomes of a Level 4 mechatronics module and become a part of the summative assessments of the module. The communication between students and industry experts was arranged periodically over the semester. From time to time, students meet with the team of eXroid and received guidance from them, at the end presented in front of the academic and eXroid personnel. There were 38 students enrolled in the module. The innovative solutions developed by each group were brilliant and diverse (Figure 5).

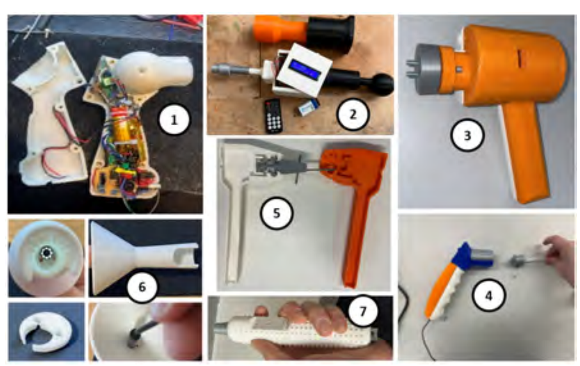

Figure 5. Prototypes of student-led solutions

Out of 38 enrolled students, 6 students did not engage effectively, either they drifted from the course or took studies interruption for a variety of reasons, but often health-related. The first-time overall pass rate was good (81%) and their average mark was 49.9 excluding zero and non-submissions and a standard deviation of 27.65. This module profile in terms of first-time pass rate was considered good, however the module learning has room for further development to improve the module class average. After evaluating students' data from student records, it was found that 100% of disabled students, 71% of female students, 40% of Black and Asian Minority Ethnic (BAME), 63% of low social, and 100 % of mature students passed the module on their first attempt. The quality of the artefacts as shown in Figure 5 was overall very good, the students lost grades through the quality of their project outcomes, report submissions and personal reflections. An NDA (non-disclosure agreement) was signed between the university and industry to preserve the development of the technology, also it will explore further opportunities for students such as internships, placement and jobs. The feedback received from eXroid regarding the project outcome was outstanding. Students also appreciated the overall learning approach, and they developed several technical and employability skills while interacting with the industry. Feedback from the students was collected for module evaluation. Attached please see a few quotes from eXroid personnel and students to show the impact.

Quotes from eXroid for several groups

"A progressive iteration on the existing device. Useful evolution of single-use probe design and like the shift in weight from the handle to box. " – Group 3
"Innovatively diverse in concept to the other groups. The standing arm is a unique concept that we really appreciated, and the remote control concept and display were really great nuggets that hit the note for significant improvements for the practitioner." – Group 5
"Really engaging presentation and the most holistic all round concept development. The rotational control; clamshell build change and connection breaking system showed real practical benefit for practitioner use, engineering production efficiency and security development." – Group 6

Quotes from students from their reflection on CDIO projects

Student 1 - 'While doing the CDIO project I've been able to improve upon my CAD (computer-aided design) skills. For these two subjects I've gained a lot of self confidence and the ability to speak with confidence during team presentations'.
Student 2 - 'I feel that as a future professional engineer I have gained a lot of new skills as well as helped contribute to my team'.
Student 3 - 'Working on a device with medical aspects was something. I believe the CDIO projects I've faced have pushed me to learn quickly and given me an excellent taste of what it's like to work for businesses. I've learnt a great deal about teamwork and how it can, with the proper structure and organization, lead to personal development and academic success.'

CONCLUSIONS

A well-designed curriculum can ensure that employability skills are integrated into the project in a way that is meaningful and effective. As engineering educators, it is important to ensure that employability skills are integrated into the curriculum to best prepare graduates for successful careers in the engineering field. The results from the case study and the feedback from students and industry personnel have shown that the industry outsourced CDIO project can be a path-breaking solution in engineering education as it can provide students with valuable opportunities to develop and apply employability skills in real-world settings. It is also reflected in their feedback that they enjoyed the learning process and enhanced their graduate attributes. Previously continuous support was provided online to disabled students in the form of additional accessible learning materials, and extra sessions so that they could catch up. This problem was partially resolved post-COVID as all sessions are now moved to face-to-face, hence in-person support was available to disabled students. This approach has been followed for the last three years and the current graduate students have received its benefits. Several students have received multiple graduate roles in different engineering sectors and others will pursue post-graduate education. After an in-depth investigation, it was found that the performance of BAME students was relatively poor (40%) compared to all cohorts, so additional training and support sessions have been arranged to close the BAME attainment gap, more inclusive methods of communication on how to foster BAME student engagement.

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BIOGRAPHICAL INFORMATION

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